Forest Service

Forest Health Protection
Blue Mountains Forest Insect and
Disease Service Center

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Subject: Review of the Lostine Project

To: Kris Stein, District Ranger, Hells Canyon NRA/Eagle Cap RD, Wallowa-Whitman NF, Region 6

I met with Supervisory Forester, Clint Foster, on May, 16th and 17th, 2016 to conduct a reconnaissance of the Lostine Project area. Our principal objectives were to assess 1) stand conditions, particularly related to species composition, horizontal structure, and vertical structure 2) activity of insect pests and disease agents, and 3) identify approaches for increasing vigor, resiliency and resistance of host trees to damage and/or mortality from key pests.

Summary

Species composition

Sites within the project area support a variety of potential vegetation types. Plant associations occurring within the project area include: grand fir/Rocky Mountain maple-mallow ninebark, grand fir/twinflower, lodgepole pine (subalpine fir)/grouse huckleberry/Jacob's ladder plant association, and grand fir/queencup beadlily (Powell et al. 2007, C. Foster, personal communication, May 26, 2016). Areas between proposed treatment units include potential vegetation types within the riparian forest potential vegetation groups.

The existing composition of tree species varies across the project area. Some of the units, particularly in the lower third of the project area, consist of one or more seral species and the climax species, grand fir. At the lower end of the project area, ponderosa pine contributes significantly to the mix of seral species along with Douglas-fir and, to a varying extent, western larch. Ponderosa pine is less frequent in the middle of the project area giving way to Douglas-fir and/or western larch and becoming rare or largely absent at the upper end of the project area. Quaking aspen is also present in Unit 4 and contributes to species diversity. However, conifers are currently encroaching on the aspen at this location. A couple of the units in the middle of the project area are occupied primarily by lodgepole pine. In some of these locations, a small number of western larch are present forming a scattered upper stratum. Units at the upper end of the project area are occupied largely by grand fir. In colder portions, units occupied primarily by grand fir also include Engelmann spruce.

Pieces of charcoal and burnt stumps were evident across the project area signifying that fire has functioned as a disturbance factor influencing plant assemblages at this location. However, the extent and intensity of fire was varied within the project area.

Portions of the project area previously visited by fire are currently occupied by seral species including ponderosa pine, Douglas-fir, western larch or a combination thereof. These species develop thick bark which protects the cambium from being killed by heat generated in fires of low to moderate intensities (Agee 1993). Western larch exhibits a high open branching habit. Douglas-fir also has a high, but dense, branching habit. Ponderosa pine exhibits a moderately high and open branching habit (Agee 1993). These species exhibit boles clear of branches and foliage in close proximity to the ground. Consequently, the likelihood of fire being laddered from surface fuels to the crowns (aerial fuels) is effectively reduced. These species are good candidates for retention during spacing treatments to provide structure and function more likely to be sustained under future disturbance events, prescribed fire and/or wildfire.

Other portions of the project likely experienced stand-replacement fire(s). In fact, downed trees/logs that were present in adjacent areas, are absent in these locations. Because surface fuels in the 100 hour (1.0-3.0 inch diameter) and 1000 hour (3.0-8.0 inch diameter) time lag classes were missing, it is likely that complete combustion of these fuels occurred consistent with higher severity fire. These areas are currently occupied by even aged stands of lodgepole pine.

Some lodgepole pine trees are able to regenerate following stand replacement fires from serotinous cones. Where serotiny is not prevalent, however, lodgepole pine is able to regenerate at a competitive advantage with other species, in part, because it is able to produce seed at an early age, typically 5 to 10 years. Moreover, lodgepole pine commonly produces good seed crops every 1 to 3 years with lighter crops occurring during intervening years. This favors lodgepole pine's ability to rapidly establish and occupy released growing space following a stand replacement fire. Other attributes that give lodgepole pine a competitive advantage over other species include good seed viability, germinative energy, early rapid growth, and wide ecological amplitude (Burns and Honkala 1990).

Other portions of the project area currently dominated by lodgepole pine exhibit a greater build-up of surface fuels including dead lodgepole pine that has been downed for many years. Egg galleries characteristic of mountain pine beetle, *Dendroctonus ponderosae,* were readily apparent in downed lodgepole pine. Mountain pine beetle killed these trees during a past outbreak most likely occurring in the 70's. These areas have not experienced fire as a disturbance agent for many years during which time considerable surface fuels have accumulated. Future fire disturbances are likely to cause greater tree mortality, loss of structure and function under these fuel loads. Conversion to more fire resistant species along with reduction of surface fuels would provide structure and function that is sustainable over the long term.

Other portions of the project area also lack evidence of past fires. These areas are characterized by assemblages of grand fir, with or without, Engelmann spruce. These moderately thick barked and thin barked tree species are vulnerable to mortality from even low intensity fires. A sample of tree ages obtained from these areas indicate that fire has been excluded from these locations for 80 or more years.

Horizontal structure

We obtained estimates of stand density across the project area to assess the level of competition induced moisture stress relative to the productivity of the site. Our estimates of stand density approached or exceeded the lower limit of the self-thinning zone or zone of imminent competition mortality. This stand development benchmark is approximated by the upper limit of the management zone (ULMZ) (Cochran et al.1994, Powell 1999). In fact, competition induced mortality has already occurred and was clearly evident across the project area.

Competition for limited soil moisture has reduced the capacity of trees to photosynthesize. Trees growing at reduced photosynthetic capacity may be unable to produce sufficient carbohydrates to allocate to all of their priorities. Moreover, the photosynthate trees produce is allocated in a particular hierarchy. Sugars are allocated first to maintenance respiration (keeping the living cells alive), followed by new foliage and fine roots, then reproductive structures (if it's a seed year), and after that, primary growth, and finally to production of secondary growth concurrent with allocations to defensive chemicals (Oliver and Larson 1990). Consequently, trees experiencing competition induced moisture stress have insufficient photosynthate to allocate to defense against key pests such as bark beetles.

We obtained increment cores from trees across the project area and measured annual ring growth in the last inch of the core to determine the impact of competition on secondary growth, an index of secondary metabolite production and susceptibility to mortality agents. The cores we examined exhibited limited annual ring growth of 15 or more rings in the last inch of the increment indicating elevated risk to mortality agents (Dolph 1983, Hall 1972). In fact, old, recent and current mountain pine beetle caused mortality of lodgepole pine was readily apparent within the project area.

Vertical structure

Vertical structure varies across the project area. In the lower portions of the project area, some stands are multi-storied. These stands are characterized by a mix of species in the upper, mid, and lower strata. The regeneration component is typically composed of shade tolerant grand fir and Douglas-fir sometimes accompanied by Engelmann spruce. Shade intolerant western larch and lodgepole pine are a component of the regeneration stratum where openings allowed more sunlight to reach the forest floor and seedlings were able to establish during good seed years.

Portions of the project area are dominated by lodgepole pine and characterized by a single-storied vertical structure. In some stands, however, western larch is also present forming an overstory component, albeit very few in numbers and scattered in distribution. These locations have a two-storied structure. Other areas dominated by lodgepole pine have a lower stratum of grand fir regeneration with or without a western larch overstory component forming both multi-storied structures and two-storied structures.

In the upper portions of the project area, a two-storied vertical structure is apparent with shade tolerant grand fir in both the overstory and regeneration strata. In locations where the overstory stratum is denser, the understory component is largely absent.

Insect and disease activity

Activity of key insect pests varied across the project area. Stands of lodgepole pine susceptible to mountain pine beetle mortality are characteristically greater than 80 years old with an average tree diameter greater than 8 inches dbh and generally between 300-600 trees per acre (Gibson et al. 2009). Much of the project area occupied primarily by lodgepole pine was at elevated susceptibility to mountain pine beetle. In fact, old, recent, and current mortality of lodgepole pine caused by mountain pine beetle was readily apparent within the project area.

We also noted a small number of overstory grand fir with dead tops symptomatic of fir engraver, *Scolytus ventralis*, activity. Fir engraver activity is often associated with lowered tree resistance. The outbreak that occurred in the Blue Mountains in 1974-1976 followed an outbreak of defoliators. Other outbreaks have been associated with moisture stress induced by drought (Ferrell 1986). Conditions at this location favoring fir engraver activity include moisture stress induced by competition in combination with the droughty conditions of 2015.

Aside from bark beetles, we also noted balsam woolly adelgid, *Adelges piceae*, infesting several small understory subalpine fir trees. However, the subalpine fir we observed at the time of our reconnaissance were seedling to sapling sized and occurred largely as advanced regeneration. Subalpine fir did not contribute significantly to the overstory component of the units in the upper portion of the project area.

We did not observe current activity by defoliators including western spruce budworm, *Choristonura freemani*, or Douglas-fir tussock moth, *Orgyia pseudotsugata*. However, these moths are key pests that have caused considerable damage in the Blue Mountains. Early instar western spruce budworm larvae overwinter in silken shelters called hibernacula in protected locations along the bole and limbs of their hosts, in bark fissures, under bark scales, moss, and lichen. In the spring with warming temperatures the larvae emerge and crawl out on the limbs and dangle from a silken thread they produce from a silk gland in their mouth. The silk thread acts as a sail and when it is severed from the branch by the wind, they disperse or “balloon” away from their current location. Western spruce budworm is favored by stands dominated primarily by host species including true firs, Engelmann spruce, Douglas-fir, and western larch

because, in part, they are more likely to encounter a host species during dispersal. They are also favored by dense stand structures primarily dominated by host trees as ballooning larvae are more likely to be captured by host trees under these conditions than in more open stands. Western spruce budworm is also favored by two-storied to multi-storied stand structures with host in the overstory and understory. Larvae eventually balloon downward where they are captured by shade tolerant preferred hosts in the understory (Brookes et al. 1987). Douglas-fir tussock moth first instar larvae emerge from eggs in the spring and, like the western spruce budworm, disperse via ballooning. So, dispersal is favored by similar stand structures (Brookes et al. 1978).

Activity of several disease agents was apparent across the project area. At one location we identified a pocket of tree mortality caused by Armillaria root disease, *Armillaria ostoyae*. We also identified sporophores of Schweinitzii root and butt rot, *Phaeolus Schweinitzii*, at two other locations. Both Douglas-fir dwarf mistletoe, *Arceuthobium douglasii*, and western larch dwarf mistletoe, *Arceuthobium laricis*, were present. We obtained dwarf mistletoe ratings in western larch ranging from a low of 1 to a high of 6. In places, however, greater than 70 percent of the host trees were infected with dwarf mistletoe with ratings ranging from 4 to 6. In other areas western larch was infrequently, albeit heavily, infected. In still other locations western larch were present without any visible infections. Two storied and multi-storied stand structures dominated by host species favor the spread of dwarf mistletoe plants. These parasitic vascular plants produce seeds that are held under pressure and are forcefully ejected 10 to 50 feet or more, depending on the species of dwarf mistletoe, wind and other factors (Halloin 2003; Worrall and Geils 2006). The seed is covered in a sticky substance called viscin that adheres to needles of host trees it encounters along its downward trajectory. Then when it rains, the viscin becomes slippery and allows the seed to slide down along the needle to the twig where it germinates a radicle to penetrate and infect the host.

Additional disease agents were active in the project area, albeit less frequently. We observed scattered infections of lodgepole by atropellis canker, *Atropellis piniphilia* and/or *Atropellis pinicola*. Indian paint fungus, *Echinodontium tinctorium,* a heart rot pathogen was found in numerous grand fir in the upper portion of the project area. No signs or symptoms of root disease or heart rot fungi were observed in the quaking aspen we examined.

Recommendations

I recommend reducing moisture stress due to competition to improve tree vigor, resiliency, and resistance to key pests. These objectives can be achieved by thinning from below and spacing leave trees to at least the lower limit of the management zone (LLMZ) (Cochran et al. 1994, Powell 1999). I further recommend that seral species including ponderosa pine, Douglas-fir and western larch be favored, where present, for retention over grand fir, Engelmann spruce, and lodgepole pine. In addition, I recommend retention of trees with good, 40% or greater, live crown ratios (Smith 1962) and height to diameter ratios of less than 80:1 (Wonn & O'Hara

2001), of good form, without current infections or infestations of key pests. Trees with current bark beetle attacks are candidates for removal. Trees with current or apparent infections of dwarf mistletoe and dwarf mistletoe ratings of 3 or greater are candidates for removal. If, however, some number of additional snags are desired for other management objectives, western larch trees with dwarf mistletoe ratings of 6 and then 5 could be retained. These severely infected trees have substantially less crown volume than moderately infected trees and consequently support fewer dwarf mistletoe plants which in turn produce less dwarf mistletoe seed. These severely infected trees are also likely to die in the short term, one or two decades (Schmitt and Hadfield 2009). Douglas-fir infected with dwarf mistletoe may also provide structure for other management objectives and could be retained where adjacent trees are non-hosts to mitigate seed dispersal and infections. Trees with symptoms or signs of Armillaria root disease or Schweinitzii root and butt rot are also candidates for removal. Lodgepole pine infected with atropellis canker, grand fir with infections of Indian paint fungus, and subalpine fir with current infestations of balsam woolly adelgid are also candidates for removal.

I also recommend thinning from below to maintain single-storied structures. Together with spacing trees and promoting non-hosts or a combination of host and non-hosts, maintaining single-storied structures reduces vulnerability to defoliators like western spruce budworm and Douglas-fir tussock moth. Under these conditions, ballooning larvae are less likely to encounter a host tree and more likely to be lost to the system, ballooning to the ground where they starve or are eaten by predators such as ants or ground beetles. Single storied structures also prevent infection of understory host by dwarf mistletoe seeds forcibly ejected from parasitic plants that may remain following spacing of overstory host trees.

Quaking aspen contributes to species diversity within the project area. The trees we examined were of good form without apparent infections of root disease or heart rot fungi. I recommend removal of the conifers encroaching on, and competing for growing space (sunlight, soil moisture, nutrients, and physical space) with aspen in Unit 4. I further recommend removing conifers around the current stand perimeter (50 feet or more) permitting expansion of aspen into the adjacent area providing suitable edaphic conditions (Swanson et al. 2010).

Other areas of the project are almost pure lodgepole pine greater than 80 years of age, with a quadratic mean diameter of 8 inches DBH or greater, and over 100 sq. ft. of basal area per acre and are at elevated risk to mountain pine beetle (Gibson et al. 2009). Trees in stands exhibiting this type of structure typically have severely reduced live crown ratios and greater height to diameter ratios compared to more open grown trees. These trees exhibit severely reduced photosynthetic surface area and are not likely to capture released growing space and improve in vigor following spacing (Smith 1962). Individual trees are also at elevated risk to loss of vertical stability, “noodling over”, following treatment (Wonn & O’Hara 2001). Stands exhibiting this type of structure present an opportunity to regenerate with fire resistant seral species such as ponderosa pine, Douglas-fir, and/or western larch.

Lodgepole pine along with western white pine are the most frost tolerant species of conifers in the Pacific Northwest (Minore 1979). For this reason, lodgepole pine is relatively more successful than other conifers establishing and occupying colder areas, particularly cold air drainages and cold air sinks. However, white pine blister rust resistant western white pine may provide a suitable candidate for replacing lodgepole pine growing under those topographic conditions. Western white pine has medium bark thickness with a high moderate branching habit compared to thin-barked moderately-low and open-branching lodgepole pine (Agee 1993) and accordingly more resistant to low-intensity fire regimes.

Western larch and ponderosa pine are both moderately frost tolerant relative to lodgepole pine and good candidates for areas outside cold air drainages and cold air sinks. Western larch is only slightly more frost tolerant than ponderosa pine. However, both species are much more frost tolerant relative to Douglas-fir (Minore 1979).

Some units in the upper portion of the project area are dominated by grand fir with or without a smaller component of Engelmann spruce. I recommend spacing grand fir to the LLMZ which will necessarily result in the creation of grand fir stumps 14 inches in diameter or greater. Stumps of this size provide suitable infection courts for annosus root disease spores (Schmitt 2001). *Heterobasidion occidentale* infects the roots of surrounding uninfected grand fir trees that come in contact with the infected stump. I recommend treatment of grand fir stumps 14 inches or larger in diameter at the time of spacing with a registered fungicide containing borax to mitigate infection of grand fir leave trees with *Heterobasidion occidentale* in these locations.

Areas between proposed units are also at stand densities greater than the ULMZ. Treatment to reduce competition induced moisture stress in these locations would also improve tree vigor, resilience, and resistance to mortality agents. An additional benefit of treating the areas between proposed units is the creation of a continuous fire break. Moreover, removal of dwarf mistletoe infected trees in areas adjacent to the proposed units would reduce infection of retained hosts within and along the boundaries of the proposed units.

Individual Units Visited

Unit 4

This site supports a grand fir/Rocky Mountain maple-mallow nine bark plant association. Most of the unit is occupied by a mix of grand fir, Douglas-fir, western larch and, to a lesser extent, ponderosa pine. Many of the ponderosa pine, Douglas-fir, and western larch present are free of dwarf mistletoe infections, exhibit good live crown ratios and would be good candidates to select from for retention. We obtained estimates of stand density ranging from 200 to 280 sq. ft. of basal area per acre, at or above the lower limit of the self-thinning zone for each of the species present. We also obtained an increment core from a dominant Douglas-fir tree 93 years old and 24.7 inches dbh with 24 rings in the last inch of the radial increment indicating the ability of the tree to produce secondary metabolites for defense has been compromised. In order to restore

vigor, resiliency and resistance to mortality agents I recommend reducing stand density to at least as low as the lower limit of full site occupancy for ponderosa pine. I further recommend retention of ponderosa pine, Douglas-fir and western larch that exhibit good live crown ratios free of dwarf mistletoe.

Armillaria ostoyae has caused tree mortality in the upper portion of the unit. This root disease pathogen is severely damaging to both Douglas-fir and grand fir. Ponderosa pine is moderately damaged and western larch is seldom damaged (Goheen and Willhite 2006). Within and around the Armillaria root disease pocket, I recommend favoring ponderosa pine and western larch with good live crown ratios free of root disease symptoms (including Schweinitzii root and butt rot), dwarf mistletoe infections or bark beetle infestations.

Phaeolus Schweinitzii is also present in this unit. Douglas-fir, and larch are seriously affected by Schweinitzii root and butt rot. Because both Armillaria root disease and Schweinitzii root and butt rot are present in this unit, however, both root diseases should be treated as Armillaria root disease problems (Hagle and Filip 2010). Favoring ponderosa pine and western larch, somewhat resistant to Armillaria, is recommended.

Conifers are currently encroaching on a stand of aspen in a portion of the unit. To improve the vigor of the remaining aspen, I recommend removal of the encroaching conifers as well as removing conifers from around the margin of the aspen stand to release growing space and provide suitable substrate for expansion of aspen.

Unit 5

This site supports a grand fir/twinflower plant association. Most of the unit is occupied by grand fir in both the overstory and understory. Many of the overstory grand fir exhibit good live crown ratios and height to diameter ratios. Where grand fir is the only available species for retention, there should be a sufficient number of suitable candidates to select from for spacing leave trees. Western larch is present and contributes to the species composition of the overstory particularly in the upper portions of the unit. In places, however, greater than 50 percent of the western larch have dwarf mistletoe ratings ranging from 1 to 5. Douglas-fir also contributes to the species mix forming a dense single storied structure in a portion of the unit. Some of the Douglas-fir in this unit have succumbed to mortality from *Armillaria ostoyae*. In addition, a number of the live Douglas-fir associated with the root disease pocket exhibit infections of dwarf mistletoe. Since both Douglas-fir and grand fir are severely damaged by Armillaria root disease, I recommend removal of all highly susceptible species and retention of, and/or regeneration with, western larch without dwarf mistletoe infections within the disease center and a buffer of 2 normal trees spacings beyond the last dead or symptomatic trees along the perimeter according to Schmitt (2001). We obtained estimates of stand density ranging from 200 to 220 sq. ft. of basal area per acre. In the denser portion of the unit dominated by Douglas-fir our estimate of stand density was 300 sq. ft. of basal area per acre. Outside of the root disease center, I recommend reducing stand

density to at least the lower limit of full site occupancy favoring western larch and Douglas-fir over grand fir where possible and grand fir of good form where alternative species are unavailable.

Unit 7

This site supports a grand fir/twinflower plant association. The vertical structure at this location varies from two to three-storied. The overstory component in this unit is composed of grand fir, western larch, Douglas-fir, lodgepole pine, and Engelmann spruce in denser, shaded, colder portions of the unit. We obtained estimates of stand density ranging from 200-340 sq. ft. of basal area per acre.

We also obtained an increment core from a dominant lodgepole pine 19.5 inches dbh that had 64 rings in the last inch of the radial increment indicating that the ability of this tree to produce secondary metabolites for defense against mortality agents has been compromised. In fact, we observed old, recent and current mortality of lodgepole pine caused by mountain pine beetle. Lodgepole pine also suffers infections of atropellis canker and western gall rust at this location. Furthermore, lodgepole pine growing under these dense stand conditions have live crown ratios less than 30 percent and height to diameter ratios exceeding 80:1. These trees are unlikely to respond to release of growing space due to their reduced photosynthetic surface area and would be at elevated risk to loss of vertical stability, “noodling over”, following treatment without neighboring trees to help hold them up.

Some of the western larch in this unit are of good form with good LCRs and suitable candidates to select from for retention. However, there are portions of the unit where 70 to 80 percent of the western larch are infected with dwarf mistletoe with dwarf mistletoe ratings of 4 to 6.

I recommend reducing stand density to at least the lower limit of full site occupancy. Lodgepole pine will not likely respond to release of growing space and should be targeted for removal favoring Douglas-fir and western larch with good LCRs and height to diameter ratios free of dwarf mistletoe.

Riparian buffer

We took a closer look at one of the areas between units. We obtained an estimate of stand density of 420 sq. ft. of basal area per acre, indicating reduced photosynthetic capacity and elevated risk to mortality agents. Spacing trees in the areas between units would release growing space to retained trees, improve photosynthetic capacity, and reduce risk to mortality from bark beetles while retaining structure that provides important riparian function including: shade to maintain cool stream temperatures, food and shelter resources for aquatic insects, and bank stabilization among other things. Treatment between proposed units would also release growing space to hardwoods that are already present to an extent, are commonly supported in riparian

forests, and effectively regulate stream temperature in concert with conifers in these locations while concurrently providing additional riparian function. (Liquori and Jackson 2001).

Unit 8

This site supports a lodgepole pine (subalpine fir)/grouse huckleberry-Jacob's ladder plant association. The majority of the trees occupying the overstory in this unit are lodgepole pine but there is a fair amount of western larch, some Douglas-fir and grand fir, an occasional ponderosa pine, a little Engelmann spruce, and even less subalpine fir. Understory species include grand fir Douglas-fir, and lodgepole pine. We obtained a stand density estimate of 220 sq. ft. of basal area per acre at this location. We also obtained an increment core from a dominant lodgepole pine 12.0 inches dbh with 55 rings in the last inch of the radial increment.

The western larch at this location are well spaced for the most part and have good LCRs and height to diameter ratios without dwarf mistletoe infections for the most part. There are some larger grand fir with good LCRs as well. Overstory Douglas-fir are also of good form and free of insect and disease. Lodgepole pine have been killed by mountain pine beetle in the past and have reduced LCRs and height to diameter ratios greater than 80:1. The few ponderosa pine we observed in the overstory were in pretty rough shape with poor crowns of reduced photosynthetic surface area. The smaller subalpine fir we examined are infested with balsam woolly adelgid. We also observed an occasional juniper. However, some of the juniper we encountered exhibited rust infections.

At this location I recommend reducing stand density to at least the LLMZ. I further recommend targeting lodgepole pine, ponderosa pine with poor crown development, subalpine fir, and juniper for removal and retention of western larch and Douglas-fir. Larger grand fir are candidates for retention where Douglas-fir and western larch are not available.

Unit 8a

This site supports a lodgepole pine (subalpine fir)/grouse huckleberry-Jacob's ladder plant association. The majority of the trees occupying the overstory in this unit are lodgepole pine. We obtained estimates of stand density ranging from 140-190 sq. ft. of basal area per acre. Live crown ratios ranged from 5 to less than 30 percent and height to diameter ratios exceeded 80:1. Infection of atropellis canker in lodgepole pine was also observed at this location. The stand structure in this 2 acre unit lends itself to the proposed group select treatment targeting lodgepole pine for removal and conversion to western larch.

Units 11, 11a & 12

These units are characteristic of a lodgepole pine (subalpine fir)/grouse huckleberry-Jacob's ladder plant association. The overstory lodgepole pine exhibit poor LCRs and height to diameter ratios that are unlikely to respond vigorously to release of growing space. We observed old,

recent and current mountain pine beetle caused mortality of lodgepole pine. The understory includes a substantial component of grand fir reproduction. Western larch is present and forms a scattered upper stratum. Many of the larch, and some overstory grand fir, have good LCRs and height to diameter ratios less than 80:1 that are good candidates to select from for leave trees. Moreover, many of the larch do not exhibit crown symptoms associated with root disease infections, or dwarf mistletoe infections.

In units 11 and 12, I recommend reducing stand density to the lower limit of full site occupancy approximated by the LLMZ for western larch in this plant association. I further recommend favoring western larch and grand fir of good form and no infections or infestations of key pests over lodgepole pine for spacing leave trees. In the embedded 2 acre unit (11a), group selection treatment can be augmented with conversion to western larch by natural seeding from retained overstory trees, planting, or both.

Units 15-23

These units are consistent with a grand fir/twinflower plant association. Grand fir dominates in unit 15 and many of these trees exhibit good LCRs. However, Indian paint fungus, *Echinodontium tinctorium*, was readily apparent in a number of overstory grand fir at this location. Engelmann spruce and lodgepole pine contribute substantially to species composition. Evidence of past mortality of lodgepole pine by mountain pine beetle was evident. Western larch, Douglas-fir, and subalpine fir are also present to a lesser extent. Stand density was estimated at 240 sq. ft. of basal area per acre.

I recommend reducing stand density in Unit 15 to the lower limit of full site occupancy. Western larch and Douglas-fir of good form should be favored for retention on a good spacing where feasible over less fire resistant thin-barked species such as lodgepole pine and Engelmann spruce. Lodgepole pine with poor LCRs and height to diameter ratios in particular should be targeted for removal. Western larch and Douglas-fir are seldom damaged by annosus root disease whereas grand fir is severely damaged (Goheen and Willhite 2006). However, spacing leave trees at this location will necessitate retention of grand fir. I recommend spacing grand fir of good form without current infections of Indian paint fungus or infestations of fir engraver where suitable Douglas-fir or western larch are unavailable.

Reducing stand density will also require removal of grand fir. Annosus root disease spores often infect freshly cut stumps of grand fir. Grand fir stumps 14 inches in diameter or greater should be treated with an EPA registered fungicide containing borax for control of annosus root disease at the time of spacing (within two days of harvest but preferably at the time the cut surface is created). Care should be taken to avoid causing injury to leave trees during spacing treatments as wounds exposing the sapwood also serve as infection courts for annosus root disease spores (Schmitt 2001).

Unit 17 is similar to unit 15 in species composition. However, there appears to be considerably more basal area in grand fir and Engelmann spruce 21 inches dbh and greater in Unit 17 compared to Unit 15. This may impact the ability to reduce stand density and moisture stress due to competition to the LLMZ. Western larch is present but few in numbers. Some of the larch exhibit good LCRs and would be suitable candidates to select from for leave trees. We obtained an increment core from a dominant lodgepole pine with 45 rings in the last inch of the radial increment indicating photosynthetic capacity is reduced and production of secondary metabolites for defense against mortality agents is compromised. In fact, lodgepole pine mortality caused by mountain pine beetle has already occurred at this location. The same recommendations for Unit 15 apply to Unit 17.

Units 18 & 19 are experiencing exceedingly high levels of competition induced moisture stress. We obtained estimates of stand density in both units as high as 500 sq. ft. of basal area per acre. We also obtained an increment core from an Engelmann spruce 29.0 inch dbh with 31 rings in the last inch of the radial increment. Western larch is present in Unit 18 but most of these trees are too spindly to recommend as leave trees. Douglas-fir is present in Unit 19 and some of these trees may be suitable candidates for retention. Most of the leave trees in these two units will be large diameter (>21 inches dbh) grand fir and Engelmann spruce. Lodgepole pine of poor form and reduced LCRs are candidates for removal. Otherwise recommendations for treatment are the same for these two units as for the previous two units, particularly reducing stand density to the lower limit of full site occupancy and treating grand fir stumps 14 inches in diameter and greater against colonization by annosus root disease pathogens.

Unit 20 is composed largely of grand fir and lodgepole pine with a smaller component of western larch. We obtained an estimate of stand density for this location of 220 sq. ft. of basal area per acre. Many of the lodgepole pine and western larch have very small LCRs and height to diameters greater than 80. Moreover, recent mortality of lodgepole pine caused by mountain pine beetle was evident at this location along with severe dwarf mistletoe infections of numerous western larch. I recommend reducing stand density to at least as low as the LLMZ. There are more than a sufficient number of well-spaced grand fir of good form and western larch without current infections of dwarf mistletoe to retain and meet the LLMZ. Accordingly, lodgepole pine with current attacks by mountain pine beetle are candidates for removal as are western larch exhibiting poor form or infections of dwarf mistletoe. If, however, some number of additional snags were desired, western larch trees with dwarf mistletoe ratings of 6 and then 5 could be retained. These severely infected trees have substantially less crown volume than moderately infected trees and consequently support fewer dwarf mistletoe plants which in turn produce less dwarf mistletoe seed. These severely infected trees are also likely to die in the short term, one or two decades (Schmitt and Hadfield 2009). I further recommend treating grand fir stumps 14 inches or larger in diameter to prevent colonization by annosus root disease spores.

Our estimates of stand density in Unit 22 ranged from 240-420 sq. ft. of basal area per acre. This location is also characterized largely by grand fir exhibiting a wide range of diameters.

Lodgepole pine, western larch, and (rarely) ponderosa pine are also present and contribute to species composition.

Three bark beetles are active at this site. Mountain pine beetle has caused mortality of lodgepole pine over a number of years as evidenced by past, recent, and current activity. Fir engraver has also been active at this location recently causing top-kill in scattered grand fir trees. One dead ponderosa pine exhibited late summer feeding galleries produced by pine engraver, *Ips pini*.

Disease agents are active in Unit 22 as well. Mortality of western larch caused by *Armillaria ostoyae* was observed, with unidentified species of flatheaded wood borers present and functioning as contributing factors. In addition, some of the western larch exhibited severe infections of dwarf mistletoe. Schweinitzii rot and butt rot was also identified at this location as evidenced by their diagnostic sporophores. I recommend reducing stand density to the LLMZ at this location. I further recommend spacing western larch, and ponderosa pine of good form without current infections of root disease agents, dwarf mistletoe or key bark beetles. Grand fir selected for retention should be free of current fir engraver attacks. Grand fir stumps 14 inches or larger in diameter should be treated to prevent colonization by annosus root disease spores. In addition, wounding leave trees should be avoided to prevent creation of infection courts. The ground is very rocky in Unit 22. Exposed boulders at this location will constrain skidding operations. Care should be taken by skidder operators as they attempt to negotiate the challenging terrain so as not to wound leave trees, especially grand fir and create infection courts for annosus root disease spores.

We obtained an estimate of stand density in Unit 23 of 340 sq. ft. of basal area per acre. We also obtained an increment core from a grand fir 19.2 inches dbh with 27 rings in the last inch of the radial increment. This unit is composed largely of grand fir and Engelmann spruce with the occasional western larch. Western larch appears to be relatively free of dwarf mistletoe infections and grand fir relatively free of Indian paint fungus. There are numerous individuals of both species to select from with good LCRs and height to diameter ratios that are suitable candidate for retention when spacing to reduce competition induced moisture stress. Like Unit 22, this unit has numerous exposed boulders that constrain skidding operations. The same recommendations for Unit 22 apply to this unit, however, there are more and better potential leave trees to select from.

Please don’t hesitate to contact me with any questions.

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